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2.6 ECOLOGICAL CONDITION INDICATORS

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2.6 ECOLOGICAL CONDITION INDICATORS [1]

This chapter summarizes reviewer discussions and presents consensus conclusions and recommendations for EPA's proposed ecological condition indicators for the ROE Technical Document. The chapter is divided into five sections. The first four cover indicators in four topic areas: extent and distribution, diversity and biological balance, ecological processes, and critical physical and chemical attributes. The fifth discusses reviewers' responses to general questions.

All indicators were reviewed by the ecological condition review group; one was also reviewed by the air group. The ecological condition reviewers ranked each indicator in terms of its importance in answering the question under which it is presented (assuming it was modified as recommended by these reviewers). These rankings appear in the upper right-hand corner of each "Consensus" table. A "High" ranking represents the most important indicators. In cases where the reviewers recommended not including an indicator, they did not assign a rank, and these indicators are labeled NA.

The following table shows the reviewers' overall recommendations for these indicators.

Table 2.6-1. Peer Reviewer Recommendations for Ecological Condition Indicators

Indicators	Include with Suggested Modifications	Don't Include Unless Critical Modifications Are Made	Don't Include
Extent and Distribution			
Forest pattern and fragmentation	✔		
Extent of coral reef cover			✔
Ecological framework	✔		
Relative ecological condition of undeveloped land	✔		
Land cover change in Puget Sound basin	✔		
Diversity and Biological Balance			
Terrestrial plant growth index			✔
Bird populations	✔		
Fish faunal intactness	✔		
Threatened and endangered species			✔
Non-indigenous species in the estuaries of Oregon and Washington	✔		
Ecological Processes			
Forest disturbance			✔
Critical Physical and Chemical Attributes			
Changing streamflows	✔		
Carbon storage in forests	✔		
U.S. and global mean temperature and precipitation	✔		

[1] At the time of this peer review, EPA intended to publish the ROE Technical Document in 2006. Therefore, this summary of reviewer discussions refers to the "2006 Report on the Environment" and "ROE06." These terms are synonymous with all references to the "2007 Report on the Environment" and "ROE07" elsewhere in this report.

2.6.1 Extent and Distribution

2.6.1.1 Forest Pattern and Fragmentation

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: High)
Critical modifications	• Display data by region. At the very least, use EPA regions, which are probably preferred for administrative reasons. • The indicator would be strengthened by establishing a reference condition for forest fragmentation (by region). This reference condition may be historical/pre-settlement, or it may reflect another date for which we have methodological confidence. Note that several national maps of reference conditions have already been developed. • To establish trends, future NLCD data will be required. The discussion of this indicator should emphasize the importance of continuing data collection, particularly the NLCD database. The reviewers encourage EPA and other federal government agencies to make every effort to guarantee the future availability of the dataset. Assuming that EPA plans to use decadal development of NLCD, broad trends could develop through time, but would require many decades to develop robust trends.
Suggested modifications	• It is also worthwhile to explore whether the data can be broken down by ecoregions.

Individually, the reviewers provided several additional comments on the proposed indicator. Following up on pre-meeting comments, one reviewer inquired about the progression of pixel sizes, as the smallest size (5 pixels squared) does not fit with the geometric pattern shared by the others (expansion by a factor of three). EPA responded that the choice of pixel size could be addressed in a question to Kurt Riitters of the U.S. Forest Service (USFS), who developed the indicator. Two other reviewers agreed that the pixel progression is odd, but said it does not detract from the indicator's usefulness or alter its interpretation.

One reviewer acknowledged that the methodology of data collection is imperfect, but said it is still the best that is presently available. Another reviewer expressed the opinion that while data collection methods may change, the uncertainty related to changing methodology should be outweighed by the usefulness of the large amount of new data that will be collected.

Several reviewers expressed concern with the ability of this indicator to measure trends in the future, particularly given the apparently uncertain future of the National Land Cover Dataset (NLCD). As one reviewer noted, NLCD is unlike many other data collection efforts in that there is no legal mandate to maintain it. When questioned about the future of NLCD, EPA noted that research plans currently exist, but that there are not yet any operational plans for maintaining the NLCD effort. Because of their shared concerns, the reviewers agreed that the indicator should include a strong recommendation that the capability to measure future trends be preserved.

2.6.1.2 Extent of Coral Reef Cover

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Do not include.** (Rank: NA)
Reasons for exclusion	• The indicator lacks calibration between methods and cannot adjust for methodological differences (quadrat versus transect). • The indicator does not identify data points collected with different methods (e.g., with different types of points on the graphic). • The indicator does not explain how sites were selected for sampling. • The indicator lacks a consistent analytical framework for adjusting for bias in geographic distribution and sampling method.
Suggested alternatives	• Indicate that this is an important area where EPA should work with other federal agencies to develop an appropriate indicator in the future.

Despite their overall decision not to include the indicator in ROE, individual reviewers noted a few strengths in the proposed indicator. Two reviewers agreed that the indicator covers an important area of ecological concern, while a third suggested that non-inclusion of other regions may be a *good* thing in this case, because data from other regions (e.g., Hawaii) may not be comparable to the Caribbean data in the proposed indicator.

Nonetheless, many of the individual comments provided by the reviewers reflected concerns with the indicator data and methodology. In particular:

- Because the data represent a "grab-bag" of sampling, the indicator may not be sufficiently inclusive.
- The indicator lacks a systematic approach within sampling sites, some of which could conceivably be no more than cursory inspections.
- The apparent trend in the graphic may in fact be due to differences in sampling method (i.e., quadrat versus transect). Comparing different things automatically introduces a bias, which the indicator writeup confirms.
- Much of the apparent downward trend could be eliminated just by removing the two points at the upper left of the graph. Thus, the apparent result—a decrease from 60% to 20%—may be misleading and unnecessarily alarming.

At the panel's request, an observer from the National Oceanic and Atmospheric Administration (NOAA) offered some clarification about existing efforts to assess coral reef cover. She explained that NOAA does have a corals program, and is currently improving its methods and developing new draft indicators. She also suggested that if the proposed indicator were included in ROE 06, it might encourage improved inter-agency efforts.

Reviewers also provided some individual suggestions as to how the proposed indicator could be improved to the point where it is suitable for future editions of ROE. One reviewer emphasized that a future coral reef indicator must reflect a standardized approach, and noted that the present indicator might just be a

useful starting point. Two reviewers agreed that while the criteria for ROE indicators require quantitative metrics, this is a case where it could be useful to transform quantitative data into qualitative categories, considering that statistics on percentage data can often be troublesome.

2.6.1.3 Ecological Framework

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: High)
Critical modifications	• Clarify the overall purpose of the indicator. The indicator title is vague, and should be refined. • EPA should look critically at the "potential land-use change" component of the indicator. If it does not meet the criteria for an ROE indicator, this component should not be included. • The indicator should clarify what the "hubs and connections" metric is measuring (i.e., define these terms). • The indicator should explicitly define other ecological terms. • The indicator should identify reference conditions—particularly a temporal reference point. This reference condition may be historical/pre-settlement, or it may reflect another date for which we have methodological confidence. • The indicator should clarify which data layers are included in each analysis, and identify any redundancies between layers. • To establish trends, future NLCD data will be required. The discussion of this indicator should emphasize the importance of continuing data collection, particularly the NLCD database. The reviewers encourage EPA and other federal government agencies to make every effort to guarantee future availability of the dataset. Assuming that EPA plans to use decadal development of NLCD, broad trends could develop through time, but would require many decades to develop robust trends.

Reviewers provided several individual comments on the proposed indicator. One reviewer observed that the indicator reflects a complex "composite of composites," which is frustrating because not all relationships are of the same type (i.e., some are linear, others are curvilinear, etc.). However, this reviewer noted that the way the indicator breaks out the five subcomponents is somewhat helpful. Another reviewer emphasized that the process of weighting components must always be somewhat subjective ("structured subjectivity") and observed that the proposed indicator seems to handle this challenge adequately.

Adding to one of the critical modifications above, one reviewer expressed concern with the use of the terms "Integrity" and "Health"—which can reflect value judgments—and suggested replacing these with terms that can be more explicitly defined.

The reviewers also discussed the future of the indicator, since—as several noted—the indicator will be especially useful if data collection continues and if it can be expanded to include other regions. One

reviewer noted the challenge inherent in applying the indicator to other regions because each region requires its own set of weighting factors. However, this reviewer suggested that the same overall approach could be effective in other regions as well. Another reviewer inquired as to why 1998 data had not yet been processed; EPA responded that there is interest in having all EPA regions process their data, but at present, the indicator is just a Region 4 pilot.

2.6.1.4 Relative Ecological Condition of Undeveloped Land

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: High)
Critical modifications	• Display primary results from the three separate models for rarity, diversity, and self-sustainability (3 maps), unless EPA can develop a functional basis for creating a composite index. • To establish trends, future NLCD data will be required. The discussion of this indicator should emphasize the importance of continuing data collection, particularly the NLCD database. The reviewers encourage EPA and other federal government agencies to make every effort to guarantee future availability of the dataset. Assuming that EPA plans to use decadal development of NLCD, broad trends could develop through time, but would require many decades to develop robust trends.
Suggested modifications	• In the future, consider applying this analysis to built lands and agricultural lands. • Identify appropriate spatial scale/resolution. Regardless of computational considerations, conduct a sensitivity analysis to determine the effects of choosing a particular pixel size. What is the influence of pixel size on results?

In suggesting that future analyses should include more than just undeveloped land, several reviewers noted that it would be useful to analyze agricultural and built lands because they are quite prevalent and they are more ecologically stressed than undeveloped land. One reviewer also noted that the definition of "undeveloped" land is complicated because some forests were once agricultural lands, which may have been forests originally (i.e., they have been modified); unused agricultural lands were also "used" at some time, even though they are still considered "undeveloped" by the proposed indicator. Another reviewer suggested that the proposed indicator might just use the term "undeveloped" as a surrogate for existing or potential wild land, and recommended not trying to ascribe any deep ecological meaning to the term.

The reviewers also discussed the spatial scale of the indicator. Although they agreed that they would like to see some confirmation that the current scale is indeed the most appropriate (see the second suggested modification above), several reviewers acknowledged some clear benefits to the proposed indicator's use of a moderate resolution rather than a high resolution dataset. One reviewer noted that a higher-resolution dataset might not be any more useful for this type of big-picture issue, while another suggested that a moderate resolution might obscure small "islands of development" (e.g., homesites) whose presence in the dataset might cause the indicator to lose sight of the big picture. One reviewer also emphasized the importance of maintaining the moderate resolution Landsat program to collect future data for this indicator.

Individual reviewers raised a few concerns with the indicator methodology. One reviewer noted that the data are divided into several bins based on a frequency curve, yet the boundaries of some of these bins seem arbitrary; in the graph, only a few bins are visibly discrete. A reviewer also wondered how it would be possible to achieve a "perfect" score of 300, given that two of the factors added to reach the total score—rarity and intactness—seem like opposites.

One reviewer suggested that in the future, the indicator could use a new frequency distribution for each new dataset. With a new set of bins for each dataset, the indicator would essentially provide a "moving target."

2.6.1.5 Land Cover Change in Puget Sound Basin

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: Medium)
Critical modifications	• Clarify *land use* versus *land cover*. If keeping the title of "land cover," EPA should clarify how land use relates to land cover (e.g., impervious surfaces). Also, since data originate from Landsat (which measures land cover), the indicator writeup should elaborate on how land use was interpreted from land cover.
Suggested modifications	• EPA might want to consider other regional analyses that include measures of ecological change (e.g., San Pedro, Camp Pendleton, Willamette Basin)—i.e., more ecologically explicit indicators.

Several reviewers commented that this indicator does a good job of providing simple, big-picture information, although several also noted a natural limitation to this type of broad depiction: that it cannot be applied to local-scale decisions. One reviewer also noted that this would be a useful indicator to apply on a national scale—especially in the form of a national map, which might inform the public about trends in other regions, such as reforestation in the Northeast.

Nonetheless, individual reviewers noted some limitations to the proposed indicator. As one reviewer noted, the indicator measures human use more than ecological condition. To translate land cover patterns into ecological terms, an indicator would ideally use ecological models. As noted in the suggested modification above, others have already used models to create measures of landscape change that are more spatially refined and ecologically robust than the proposed indicator.

2.6.2 DIVERSITY AND BIOLOGICAL BALANCE

2.6.2.1 Terrestrial Plant Growth Index

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Do not include.** (Rank: NA)
	• The results are too ambiguous and not explained or, perhaps, unexplainable. If you cannot interpret the trends in the indicator with logical scientific process explanations, then it is a valid scientific question, but not a public environmental indicator. • NDVI is a crude measure of growth. Chlorophyll is only a correlate of productivity, not an actual measure of gross primary productivity. • High variance of the 13-year record makes interpretation questionable. The relative deviation of the Plant Growth Index (20–40%) without explanation during the period of analysis suggests that the indicator might lack the precision needed to assess national trends in productivity. Note that in the acid rain program, effects on NPP purported to occur in the range of 1% or less were presented as strong indications of major impacts. Similarly, projections of likely consequences of global climate change are based on annual changes of ~1%. Can an indicator that fluctuates some 40% ever help one understand consequences of such subtle annual shifts? Are there any efforts to ground-truth the remotely sensed projections? Clearly, this is not ready to be used to characterize trends in plant growth.
Reasons for exclusion	• Conceptually this should be a good measure of chlorophyll and related processes such as biomass production and carbon dioxide uptake. The use of band rationing in the NDVI has a long record of effective use of satellite data linked to the biological production and carbon processing across diverse terrain and land covers. However, features of the indicator graphic, such as the extreme high in 1993 for grassland and the lower index for all covers in 1995–2000, then a sharp rise in 2001 and decline in 2002, do not show trends that are useful as an indicator of any of the ecological conditions in the ROE. • It is unclear why the indicator was calculated using political boundaries (counties) instead of a more science-based delineation of the landscape. • Methodological problems are numerous and largely unanswered. For example, there is some uncertainty concerning the meaning of the data given shifts in satellite orbit and chances of satellite failure. • The data are pre-processed with little or no access to the original data to develop an independent judgment of QA. • The Normalized Difference Vegetation Index is not clearly explained. • Continuity of use of NDVI is uncertain as there may be more suitable indices available.

All four reviewers agreed that the Terrestrial Plant Growth Index should not be included in ROE because it is conceptually flawed, as noted extensively in the pre-meeting comments and in the consensus statements above.

2.6.2.2 Bird Populations

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: High)
Critical modifications	• Be sure to clarify that the indicator is looking at the number of species with an increase in observations (index of abundance), not a change in the number of species. • In "What the Data Show," be consistent with the graphic in terms of the use of percentages and/or numbers. If statistics are presented as percentages in text, actual numbers could be included in parentheses. • When describing changes is population, use the term "substantial" rather than "significant" to avoid confusion with statistical significance (indicator uses 2/3 change as operational measure).

Individually, some of the reviewers expressed concern about certain aspects of the data collection methodology. One reviewer noted that some researchers have criticized the use of the Breeding Bird Survey (BBS) as an indicator of abundance because it does not account for many important environmental and seasonal factors. Another reviewer mentioned that there is an ongoing inquiry into the frequency of observation in the BBS.

Nonetheless, individual reviewers expressed confidence in proposed indicator, so long as the recommended modifications are made. The reviewer who mentioned the effort to study observation frequency noted that the primary researcher in that effort has indicated that the BBS *is* adequate to describe trends over a 15-to-20-year period; seasonal factors are more of a problem with short-term comparisons. This reviewer also noted that the BBS has a consistent set of sampling sites and a system for tracking the individuals who participate in the survey. One reviewer observed that the writeup for the proposed indicator already discusses many of the BBS's limitations in a clear, accurate manner. Another reviewer emphasized the importance of having an indicator on birds, even if there are some inherent limitations.

2.6.2.3 Fish Faunal Intactness

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: High)
Critical modifications	• In addition to the present map, provide graphical representation of absolute numbers of extirpated species within a hydrologic unit code (HUC). • *If* the source database includes alien species, provide a graphical representation of these numbers as well.

Overall, the reviewers agreed that the indicator should be included in ROE with modifications. Still, one reviewer noted that there may be a tradeoff inherent in the indicator: that by using 6-digit HUCs instead of 8-digit HUCs, the indicator reduces sampling error but may also miss important early warning signals. Another reviewer agreed that the indicator focuses more on extinctions than on early warning signals, and thus it indicates an extreme and undesired condition, i.e., the extirpation of species after the damage has been done.

In their individual comments, reviewers elaborated on the two critical modifications listed above. Regarding the first modification, several reviewers emphasized that the present indicator does not provide a good sense of the historical starting point for each region. For example, they noted that the desert Southwest had few fish species to begin with, so the loss of just a handful of species can signal a high level of concern; conversely, the loss of the same number of species in a place like Tennessee would seem less alarming because the baseline number of species is so much higher there. Individual reviewers had several ideas to help clarify the historical baseline:

- Show the change in number of species in *absolute* terms, perhaps on a separate map.
- In addition to the map, present a table with the absolute numbers of extinctions.
- Along with the absolute numbers of extinctions, present a map or histogram showing the number of historic species, for context. One reviewer noted, however, that there can be considerable uncertainty in the historical data on species abundance.
- In the e-ROE, allow the user to click on the map and see the underlying contextual data (i.e., historical abundance and absolute change).

Individual reviewers also explained their interest in non-native species. As one reviewer noted, the deliberate introduction of non-native game fish has created a major pressure on native species. Another reviewer noted that ROE presently has just one indicator of non-native species, and it is not national in scope (Non-Indigenous Species in the Estuaries of Oregon and Washington). While the reviewers were not sure if data on alien species were part of the original dataset for this indicator, one noted that fisheries groups and ichthyological societies do track non-native species, should additional data be needed.

Finally, one reviewer suggested that the term “extirpation” would be more accurate than “extinction” in this context, because the indicator measures whether a species has disappeared from a given watershed, not whether it has completely disappeared from the earth.

2.6.2.4 Threatened and Endangered Species

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Do not include.** (Rank: NA)
Reasons for exclusion	• This is a Level 1 indicator (administrative). Thus it should not be included in ROE 06. • The indicator reflects both administrative capacity and the listing process, but says little about the actual numbers of threatened or endangered species. Administrative, legal, and political effects on the listing process make it difficult to sort out the adequacy of the indicator, and whether the trends, especially in the 1999–2002 period, are a true reflection of trends in biodiversity. • The proposed indicator is very likely to suggest false interpretations.
Suggested alternatives	• Discuss the absence of this indicator in the chapter text (e.g., as a data gap).

The reviewers recommended unanimously that this indicator be excluded from ROE, and their individual comments are all essentially reflected in the consensus language above. As one reviewer noted, the idea of the indicator could be useful, but the implementation is poor.

2.6.2.5 Non-Indigenous Species in the Estuaries of Oregon and Washington

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: Medium)

Critical modifications	• The indicator needs a better definition of "exposed/minimally exposed." Consider the extent to which the second graphic (which uses these terms) is really an important addition to the indicator.
	• For both figures, clarify how and why these particular bins were chosen.
	• Explain several important limitations:
	  ○ It is important to make clear in the text that the experimental design is designed to represent the region, and representation of smaller spatial extents (e.g., estuaries) is limited. Note that the coastal EMAP survey *is* designed to allow data to be broken down by state.
	  ○ Note that the annual EMAP survey is insensitive to seasonal variations.
	  ○ Note the limitations of using a proportional index as an indicator. It might be beneficial to indicate the regional differences in the numbers of non-indigenous and indigenous species that went into the calculation of the index.
	• Consider other ways to display data, e.g., a frequency distribution, a cumulative frequency distribution, bins with numbers displayed.
	• Use a less ambiguous term than "grab sampling," which may be misunderstood by the public.
	• Provide improved documentation to support this indicator (e.g., Henry Lee's paper).

In their discussion, reviewers elaborated on several of the modifications recommended above. Individual comments included the following:

- It is somewhat unclear how each estuary's exposure to ballast water is determined, and how the categories of "exposed"/"minimally exposed" are defined.
- The current bins seem like crude categories, and the indictor does not justify the way they were selected.
- Some non-native species are present year-round, but others are seasonal. One limitation of this indicator is that EMAP data are only collected during one season (summer), so the indicator may not capture the full range of seasonal variation in non-native species.
- Although the public may have a tough time grasping a cumulative frequency distribution, this may be the most accurate way to present the data. Alternatively, the indicator could do a better job of using bins to show results.
- Although grab sampling is scientifically familiar, the name implies some level of randomness and inconsistency. It may be worthwhile to clarify this term or use a less ambiguous name.

- Henry Lee's paper presents more data from this dataset—extending from San Francisco Bay to Washington—and also presents more information about proportionality and representativeness in the survey design.

Reviewers focused much of their discussion on the issue of sample design. There was some initial concern about the variable nature of sampling (1 to 28 samples per estuary). However, through some outside research, the reviewers confirmed that the survey used a probabilistic design to characterize estuarine habitats in general—not to characterize each individual estuary, since some smaller estuaries had only a single sample. As one reviewer noted, this approach makes it difficult to characterize each estuary as to whether it is "invaded," as Figure 2 attempts to do. In general, these data should not be distilled down to the level of individual estuaries.

A related issue concerns the dynamics of non-native species establishment. One reviewer noted that some invasive species establish themselves at the top of the estuary, others at the bottom. Thus, a single station might not detect an invasive species in an estuary simply because of its location. As another reviewer noted, invasive species tend to establish themselves in non-random clusters. Thus, if one large estuary with a high number of samples is invaded, it can strongly influence the overall results.

Reviewers pointed out several limitations to the proposed indicator. Although one reviewer emphasized that the indicator is more scientifically credible than previous studies, several reviewers highlighted the fact that the indicator conveys nothing about differences within each region. Two reviewers also observed that the samples are not all truly independent. Because non-native species may spread easily within a single estuary, multiple samples in a single estuary are more likely to show similar results. One reviewer identified a limitation in the spatial extent of sampling, noting that Henry Lee's original dataset extended south to San Francisco, yet the proposed indicator only covers Washington and Oregon—perhaps to conform with EPA regional boundaries.

Finally, the reviewers made several observations about the ability to apply this indicator to other regions and to update this indicator in the future. Regarding spatial expansion, several reviewers pointed out that the indicator methodology is specifically suited to soft-bottom estuaries. While this methodology is appropriate for the Northwest—where soft-bottom estuaries are the dominant type—it may not be applicable on a national scale. However, like other EMAP projects, this survey *has* been designed to allow temporal comparisons in the future. Henry Lee's paper provides more details on this aspect of the survey design.

2.6.3 ECOLOGICAL PROCESSES

2.6.3.1 Forest Disturbance

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Do not include.** (Rank: NA)
Reasons for exclusion	• As discussed extensively in the pre-meeting comments, the indicator is limited in many aspects of its coverage: temporally, spatially, and in types of disturbances. • Ecological interpretation of disturbance patterns is difficult. In some cases, the lack of disturbance events (e.g., fires) may be ecologically detrimental.

As noted above, the reviewers identified several significant problems with this indicator. Many of these problems were already discussed in the pre-meeting comments, and the reviewers agreed that the pre-meeting comments provide sufficient justification for excluding this indicator from ROE. However, the reviewers did expand upon some of the key issues in their individual comments, which included the following observations:

- Ecological interpretation of the indicator is questionable. For example, the lack of fire may actually represent an ecological disturbance, while fire suppression can lead to overcrowded forests that are more conducive to insect and disease outbreaks.
- In general, the data are questionable.
- The three disturbance categories are not mutually exclusive, so there may be significant double-counting. In reality, there can be a strong interdependence among the three types of disturbances. For example, insect damage can make trees more susceptible to disease, and dead or diseased trees can be more prone to fire.
- The indicator does not address timber harvest, which disturbs more acres than fires, insects, or disease.
- The extent to which the indicator covers non-government forestland is unclear.
- The graphic does not tell the whole story about historical variation in forest disturbances. For example, if the fire graphic were extended back to the 1800s, it would reveal large amounts of forest burned by settlers. The recent low levels of burning reflect fire suppression. Thus, ecological interpretation of this indicator is complex and potentially misleading.

2.6.4 CRITICAL PHYSICAL AND CHEMICAL ATTRIBUTES

2.6.4.1 Changing Streamflows

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: High)
Critical modifications	None required.
Suggested modifications	• Clarify the text under "What the Data Show," which is currently difficult to interpret. • Consider breaking Figure 1 into two graphs: *timing* and *magnitude*. These are currently lumped together. • In the writeup, clarify text regarding the baseline period (20 years, within 4 years of target window 1930–1949).

The reviewers agreed that this indicator should be included in ROE, and they did not identify any critical modifications that must be made. However, they did discuss several suggested modifications (see above), which their individual comments describe in greater detail.

One reviewer found the text under "What the Data Show" to be convoluted, especially in its attempt to describe the graphics. This reviewer felt that the graphics do a much better job of communicating the

data. However, another reviewer appreciated the use of percentages *and* exact numbers in the text, since many indicators presented only one or the other.

Regarding Figure 1, a reviewer expressed concern that "changes" could reflect changes in either timing or magnitude, and suggested that the graphic be broken into two components in order to avoid lumping the two different effects together.

In addition to their suggested modifications, the reviewers discussed one general weakness of the indicator—the question of how to interpret the results. The reviewers agreed that changes apparent in the graphic probably do not reflect dam construction, as most dam construction occurred before the period of record (1970–1999 for the part of the indicator dealing with general changes in flow). A reviewer identified another confounding factor, however, noting that the indicator says nothing about the relationship between streamflow and precipitation/evaporation. This reviewer wondered what the indicator can really tell the audience, so long as it is not normalized to account for variation in precipitation. Nonetheless, another reviewer pointed out that the indicator shows a 75% change in flow patterns—a change that probably cannot be attributed entirely to precipitation patterns.

Reviewers addressed the question of how to present information about precipitation. One suggested adding a comparison with precipitation in future versions of the indicator, while another noted that precipitation data could also provide useful information about flood control. However, another reviewer suggested that precipitation data might be hard to incorporate because of complicated effects like snowmelt and timelag—as well as the extra complication such data would add to an already complex graphic. A reviewer pointed out that one cannot make a single national adjustment for precipitation—since it varies by region—yet this reviewer also noted that there may not be adequate precipitation gauge coverage to characterize patterns in every individual watershed.

Finally, a reviewer noted that withdrawals for irrigation can affect streamflow. Irrigation needs may also be tied to precipitation patterns, suggesting that the factors that confound this indicator may be complex and interrelated.

2.6.4.2 Carbon Storage in Forests

Reviewed by the Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: Medium)
Critical modifications	• In the text, provide an indication of the importance of the forest carbon sink with respect to the overall U.S. carbon flux and carbon budget. • Clarify the extent to which "timberland" is representative of forest land as a whole.
Suggested modifications	• To be more representative of the national carbon budget, expand the indicator to other land cover/land use types (e.g., agricultural, grasslands, urban) and other forest lands not covered by the current indicator or its data source (the FIA survey).

Overall, the reviewers agreed that this is a useful indicator that should be included in the ROE. However, in their consensus statements (above) and their individual comments, the reviewers highlighted several key limitations.

One reviewer expressed concern that the indicator is not based on actual measurements. Another reviewer agreed with this concern, noting that the indicator data were derived using various biomass equations—which are fairly well developed for the aboveground parts of the forest, but less reliable for biomass below ground. Further, as noted in the indicator writeup, the dataset does not include carbon in soil. However, as another reviewer observed, the biomass equations themselves are well documented.

Noting the indicator's reliance on biomass equations, one reviewer wondered how much one gains by taking the extra step of converting biomass to units of carbon—particularly when extra steps like this could confuse the audience. Another reviewer observed that the extra step is useful because it allows the indicator to be interpreted as a part of the global carbon budget. Thus, the reviewers agreed that it would be good to give the audience more information about the indicator's global context (see critical modification above). One reviewer specifically suggested telling the reader what percentage of the nation's carbon budget is related to storage in forests.

Another issue of interpretation raised by reviewers was the influence of harvesting. As several reviewers noted, the rate of carbon storage decreased in the most recent time period, with much of the drop attributed to increased harvesting in the South. One reviewer suggested that it might be more accurate to treat this as an indicator of forest dynamics.

Reviewers discussed one more notable issue: the indicator's limited spatial extent. As one reviewer pointed out, the indicator misses many important carbon sinks by not covering soils, grasslands, and other non-forest ecosystems. In particular, this reviewer noted, grasslands have a great deal of biomass below ground, and that a lot of carbon is lost to the atmosphere when forests and grasslands are converted to agriculture. Even within forests, the indicator is limited; as several reviewers noted, the data only cover timberlands. One reviewer suggested perhaps changing the title to reflect this limitation, and all agreed that the writeup should say more about the extent to which timberland is representative of all of the nation's forest land. Still, one reviewer emphasized that the indicator is simply limited to the extent of the FIA database, and while this may not be ideal, it is what EPA has to work with for now. Another reviewer agreed that it is important for EPA to have indicators that address the important issue of carbon flux.

2.6.4.3 U.S. and Global Mean Temperature and Precipitation

Reviewed by the Ecological Condition Group and the Air Group

Ecological Condition Group

Consensus Statements	
Overall recommendation	**Include with modifications.** (Rank: High)
Critical modifications	• Explain what the lighter lines on the graphics represent. • Provide an indication of whether the numerical trends in the graphics are statistically significant (i.e., are the slopes significantly different from zero?).
Suggested modifications	• Consider whether there are ways to add information about annual maximum/minimum temperatures, which can be ecologically significant.

Individually, reviewers elaborated on some of the modifications recommended by the group. For example, one reviewer wondered if some of the less pronounced trends in the graphic might be insignificant. A reviewer cautioned that discussing significance could lead to debate over the choice of date interval, although another noted that the choice of date interval is fairly obvious here, since it covers the last full century. Two reviewers commented that seasonal maximum and minimum values might also be important to look at, since climate extremes have a lot to do with defining the ecological response.

Regarding interpretation, one reviewer observed that the indicator says nothing about any underlying reasons for changes in temperature and precipitation. Further, the reviewer noted that regional changes are not necessarily tied to regional sources or stressors, since climate change is a global phenomenon. Another reviewer agreed that the indicator reflects a global issue, but also emphasized that it is important to at least have descriptive information like what is presented in this indicator. A third reviewer agreed, saying that this indicator provides baseline information that people could find useful.

Air Group

Consensus Statements	
Overall recommendation	**Include with minor revisions.**
Critical modifications	None.
Suggested modifications	• As described in more detail below, the indicator writeup should provide a more detailed account of the underlying data and how trends in temperature and precipitation relate to the much larger issue of global climate change. • The reviewers suggested that EPA make minor revisions to the figures and, where feasible, interpret the variability in trends observed across the different climatic regions.
Other comments	• For a more complete account of climate change issues, the reviewers recommended that EPA include additional indicators in ROE to track sea level rise and sea surface temperature.

The peer reviewers agreed that changes in mean temperature and precipitation provide important insights on the state of the environment and recommended that this indicator remain in ROE. The peer reviewers classified their comments primarily as minor revisions:

- **Additional context on climate change.** The peer reviewers agreed that the indicator writeup, by itself, provides a fairly incomplete account of how changes in temperature and precipitation fit into the bigger picture of climate change. For instance, the indicator text does not describe natural fluctuations in climate and anthropogenic pressures suspected of contributing to climate change. Further, the text provides no insights on the human health and environmental effects (both beneficial and detrimental) associated with climate change. The reviewers listed several potential effects that could be acknowledged, such as increased sea surface temperature, increased severity and frequency of storms, altered ozone formation processes, and increased vector-borne disease due to growing mosquito populations.
- **Questions regarding the underlying data.** The peer reviewers suggested several revisions to the indicator writeup to provide further insights on the underlying data set. First, some reviewers

suggested that the writeup describe how monitoring stations were selected and explain why data on temperature and precipitation are presented for different time frames. Second, peer reviewers recommended that EPA elaborate upon (in the "Indicator Limitations" section) the significance of any biases introduced by changes in instrumentation (e.g., is it possible that these changes account for most of the trends depicted in Figure 351-1 and Figure 351-2?). Finally, one peer reviewer wondered if the data trends for certain monitoring locations might be influenced by urbanization: some monitoring locations might have originally been sited in rural settings, but are now currently in populated areas due to urbanization. The indicator should explain if data were adjusted to account for urbanization or should acknowledge the uncertainties introduced by this possibility.

- **Graphs.** In the lower right-hand corner of both Figure 351-1 and Figures 351-2, long-term trends for the United States are compared to global trends. To facilitate comparisons, the plots should be shown on the same scale (for both x-axis and y-axis). The reviewers agreed that it is acceptable for the figures to break the national data down into climatic regions, but they recommended that the indicator explain what the climatic regions are and what they represent because all other air indicators break data down into EPA regions. Some reviewers recommended that EPA provide additional insights on the trends depicted in the figures. For instance, regarding the reported increase in precipitation in the United States (i.e., 4.5 millimeters/decade), one reviewer asked about the magnitude of the p-value and standard error and whether the trend is statistically significant. Further, several reviewers noted considerable differences across climatic regions (e.g., the temperature change observed in Alaska is markedly different from that observed in the Southeast). The reviewers recommended that the indicator text explain why such variations are observed, to the extent possible.

2.6.5 RESPONSE TO GENERAL QUESTIONS

2.6.5.1 General Question 1: Relative Value and Importance of Indicators

Question 1 of the general comments related to the relative importance of the various indicators. Each of the reviewers responded to this question with extensive pre-meeting comments (see Appendix 2C). During the meeting, reviewers essentially answered this question by ranking the indicators within each of the five ecological questions. Additional notes from that discussion are as follows:

- Non-Indigenous Species is "Medium" because it is limited to benthic organisms.
- Fish Faunal Intactness gave good detail in the background. Bird Populations was also good in this regard.
- Carbon Storage is "Medium" because it is limited to forests.
- SAV might not tell us much if expanded to be a national indicator.

2.6.5.2 General Question 2: Proposed New Indicators

Question 2 asked the reviewers to suggest any new indicators that they would like to see included in ROE. Over the course of the meeting, the reviewers suggested many new indicators, as well as other areas that might be interesting to study, but where extensive data have not yet been collected. The following are consensus statements on potential new indicators of ecological condition:

Consensus Statements for Question 2

- Develop an indicator that addresses either invasive species or non-native species.
- Develop a standardized classification system for land use/land cover across the nation.
- Use this improved national land cover dataset (comment #2) to track riparian conditions (e.g., extent of historical floodplain area or length of river networks that is forested).
- Apply the improved classification system (comment #2) to developed lands—e.g., to measure the extent of impervious surfaces.
- In the future, include fresh water indices from EMAP.
- In addition to the current indicators, explore the feasibility of an indicator for surface waters, especially lakes and reservoirs (use data from the EPA lake survey program).
- Explore whether new indicators can be developed to track terrestrial consumers (particularly mammals).
- Explore whether new indicators can be developed to track amphibians and reptiles.
- Develop indicators to fill the current gap in the ROE's coverage of ecological processes. Potential future indicators include chlorophyll/primary production.
- Examine the approaches used by the Coastal Indicators Research Program. Foster collaboration between this program and coastal EMAP in the development, application, and evaluation of ecological indicators.
- In developing future indicators, consider the ability to project future trends.

Individual comments from the reviewers offer additional details about the suggested areas for new indicator development. Comments include the following:

- **Invasive or non-indigenous species** are only addressed once by the current indicators. It would be nice to see more data, since there has been extensive work on phragmites, purple loosestrife, cheat grass, tamarisk, and other species. While these data may not be of indicator quality yet, they could be useful as indicators in the future. In particular, it would be interesting to see the Breeding Bird Survey used as an indicator of non-indigenous species. Another idea would be to create a broader indicator called "Ecological Impact of Non-Native Species," depicting the number of non-native species present in a given area.
- **Riparian condition** is very important for aquatic ecosystems. FIA started counting riparian forestland in the late 1990s, so a future indicator could use this dataset. Riparian extent has also been measured using remote sensing in the Willamette Basin, and the results were only slightly changed by altering the width of the riparian area (determined by the number of pixels on each side of a stream used to represent the riparian area).
- It would be interesting to look at per-capita environmental impacts (e.g., work by Costanza) or other measures of **ecological footprint**.
- A national indicator of trends in **hypoxia** would be useful, as long as a consistent metric can be established.
- There should be more coverage of **lakes and reservoirs**. While the reasons for removing the Lake Trophic indicator are understandable, it is still important to have some information about lakes.

- A big gap concerns **ecological processes**. Chlorophyll and primary production would be useful to examine on a national scale (production does appear in the regional Ecological Framework indicator).
- There is no overall indicator of **biodiversity**.
- The indicators do not cover any **terrestrial consumers** other than birds. While large mammals are too heavily managed to be good indicators, other ideas include raptor surveys, the Audubon Christmas Count, smaller mammals, and pathogens that affect mammals (e.g., hantavirus, prairie dog parasites).
- The decline in **reptile and amphibian species** has received national attention, and might be a useful indicator if the data are available—and if these species are truly ecological sentinels.
- Although there are many **coastal indicators**, it would be useful to look at ways to improve the overall coastal monitoring approach.

Finally, in the course of their discussion, the reviewers provided several additional insights related to overall concerns and overarching thoughts on ROE and the indicator process. The following general statements reflect the consensus of the group:

Consensus Statements for Other General Comments

- It would be useful to develop a future report on the anthropogenic drivers that affect ecological condition. Discuss topics such as energy use, water withdrawals, concentrated feedlots, etc.
- EPA should explore ways to compile information about futures projection (i.e., quantitative methods) and the results of existing futures assessments.
- See general note on NLCD, as discussed under the indicators on Land Cover and Land Use.
- Several indicators are based on the integration of various data in a geographically referenced frame employing a geographic information system (GIS). Accuracy of data can be assessed statistically for single mappable data sets, such as the NLCD. However, it is important to note that the current state of the art cannot assess error propagation generated by complex factor prioritizations, reclassifications, multiple utility assignments, and spatial analysis decisions through multiple dataset combinations and modeling, as is done using a GIS for these indicators.

In addition, reviewers provided many individual comments on general issues. These comments include the following:

- In general, it is important to note that remote sensing technology is constantly changing, and changing science can complicate trend analysis.
- In the overall ROE framework, it would be nice to see some overall indicators that establish trends (e.g., Land Cover), and then a subset of indicators that use more complex models to go a step further and tell us “what does this mean?”
- The Group 2 indicators seemed better overall than the Group 1 indicators.
- As noted under Land Cover and Land Use, there is a need for land classifications that are more consistent and more useful with respect to ecological condition. Many government agencies collect data, and while these agencies all have different objectives, there may still be room for a more standardized approach.

- Virtually all of the indicators lack error bars or other basic statistics to describe the precision of the data. This may be justifiable if the purpose of ROE is merely to *indicate* trends. But without the necessary statistical analysis, these indicators cannot be relied upon to demonstrate *exact* trends. This distinction needs to be emphasized.
- Uncertainty should be discussed prominently, perhaps in the overall introduction to ROE. One reviewer specifically suggested using NASA's definition of the different types of uncertainties. Also, it would be helpful to pull some of the uncertainty information from the metadata forms (and from the Web links they reference) into the actual ROE document.
- Many of the key drivers of ecological change—e.g., energy consumption—are not included as indicators. Perhaps EPA could produce a separate report to provide the public with information about the various drivers of environmental change. Concentrated feedlots are another interesting driver, since they can cause noticeable nitrate spikes in groundwater and may also lead to the transfer of antibiotic resistance.
- The indicators need a consistent set of rules. Some indicators (e.g., some of the regional indicators) are less rigorous than others.
- Scrutinize the output of coastal and Great Lakes monitoring programs to make sure the methods are consistent.
- EPA should continue to develop its collaboration with the Heinz Center.